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Response of Germination and Seedling Growth of Pepper cultivars to Seed Priming by Plant Growth Regulators

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Abstract
In order to study the germination and growth of pepper seeds, a factorial experiment based on a completely randomized design with three replications was conducted. The first factor was consisting of five cultivars of pepper (Marquiza, Cadia, California Wonder, California Wonder 310 and California Wonder 300) and the second factor was gibberellic acid with three levels (0 as control, 250 and 500 ppm), and the third factor was naphthalene acetic acid with three levels (0 as control, 50 and 100 ppm). The results showed that the highest germination percentage (89.9%- California-Wonder 310 cultivar), rate of germination (0.85- California-Wonder 310 cultivar), shoot height (95.99 mm- California Wonder 300 cultivar), shoot fresh weight (6.62 g- California Wonder 300 cultivar) root fresh weight (3.46g- California Wonder 300 cultivar), root length (15.85 cm- Marquiza cultivar), leaf length (5.36 cm-Cadia cultivar) and stem diameter (26.91mm- California Wonder 300 cultivar) were obtained from the concentration of 500 ppm GA_3 and 100 ppm NAA. The maximum seed vigor index (749.6) was detected in 0 ppm GA_3 and 100 NAA in California Wonder 300 cultivar. The 500 ppm concentration of GA_3 and 0 NAA in California Wonder 310 cultivar caused the highest leaf number (3.96). No significant differences were obtained for leaf area and leaf width among all tested concentrations. It can be concluded that seed priming of pepper with plant hormones (GA_3 and NAA) is a proper strategy for improving germination and growth traits of pepper plants.

Keywords: *Capsicum annum* L., gibberellin, plant hormone, naphthalene acetic acid.

Introduction

Capsicum species from the *Solanaceae* family are native to the tropical and humid zones of Central and South America. These species are now widely spread throughout the tropical and sub-tropical part of the world as the most important source of vegetable (Zimmer et al., 2012). Among 31 wild species, 5 species (*C. annuum* L., *C. chinense Jacq*. C. *frutescens* L, C. *baccatum* L. and C. *pubescens*) have been domesticated (Bosland and Votava, 2012).

Germination and seedling emergence are the critical stages in *Capsicum* plant life cycle. *Capsicum* as a tropical crop germinates properly at 25-27°C (Hartmann et al., 1988) but slowly in cold temperatures, increasing the susceptibility of seeds and young seedlings to disease. Rapid and uniform seedling emergence is

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essential to attain early maturity, uniform plant stands and high yield by reducing the risk of disease attack (Cheng and Bradford, 1999). One of the major concerns related to *Capsicum* cultivation is its germination pattern. It is very important to improve the germination of this species to establish uniform growth and successful yield from seed growing plants (Bewley, 1997).

Germination process is influenced by temperature and seed moisture content. Seed priming is a commercially successful practice and an efficient method for regulating the germination process. Using this practice, we will be able to enhance rapid and uniform emergence to achieve high plant vigor and growth (Singh et al, 2015).

Seed priming decrease necessary time for germination and seedling emergence and to synchronize emergence (Parera and Cantliffe, 1994). Different priming treatments have been created to increase the conformity and speed of seed germination (Finch-Savage et al, 2004). Several types of seed priming including hydropriming (drum priming) and osmo-priming (Osmo-conditioning) are generally applied to improve germination of seeds. Hydropriming is a non-osmotic method of seed priming that attained by continuous or successive addition of a limited amount of water to the seeds. Osmo-priming (Osmo-conditioning) is the standard priming technique to increase uniform emergence, and growth of plants. In this technique seeds are incubated in well-aerated solutions such as PEG and KCl and priming with plant growth hormones (Tian et al, 2014). Different hormones (e.g. IAA, GA, and NAA) are also used for seeds priming. Plant hormones such as gibberellins are efficient in breaking dormancy and causing rapid germination of seeds by antagonizing ABA activity. The aim is activation of ABA catabolizing enzymes and inhibition of the ABA related biosynthesis pathways to decrease ABA levels (Atia et al., 2009). Naphthaleneacetic acid (NAA) is a synthetic auxin plant hormone that significantly enhances seed germination (Kanmegne et al, 2007).

There are many examples for seed priming by plant hormones, for instance hormonal-priming of maize seeds with 100 mg L^{-1} GA_3 for 24 h resulted in improvement of germination rate, mean seedling emergence time, germination index and decrease in mean germination time (Afzal et al, 2008). Yogananda et al. (2004) reported that priming with GA_3 (200 ppm) led to a significant increase in germination, germination rate and seedling vigor index, root and shoot length and seedling dry matter in bell pepper seeds. Seed priming with acetylsalicylic acid and salicylic acid has been reported to improve germination and resulted in greater uniformity of germination and establishment of seedlings under high salinity conditions (Khan et al, 2009).

Therefore, the objective of the present study was to analyze the effect of hormonal priming with GA_3 and NAA on germination traits and some characteristics of pepper plants and to determine the best combination for GA_3 and NAA concentrations for improving germination and growth of different pepper cultivars.

Material and methods

Source of Seeds

Seeds of five pepper (*Capsicum annum* L.) cultivars (Marquiza, Cadia, California wonder, California wonder 300 and California wonder 310) were surface sterilized in 2.5% sodium hypochlorite solution for 10 min, then rinsed with autoclaved water and air dried. Then, the weight of 1000 seeds was measured.

Plant Growth Regulator priming

Plant hormonal treatments were performed using different concentrations of GA_3 and NAA. Three levels of GA_3 (0 as control, 250 and 500 ppm) and three levels of NAA (0 as control, 50 and 100 ppm) were used for seeds priming.

For the preparation of 250 ppm and 500 ppm GA_3, 0.25 g and 0.5 g of GA_3, was put in a measuring flask and volume was increased to 1000 mL. For making of 50 ppm and 100 ppm NAA, 0.05 g and 0.1 g of NAA was put in a measuring flask and volume was increased to 1000 ml.

Germination tests

Seeds were placed in Petri-dishes and primed with different concentrations of GA_3 and NAA for 6 h. Then, seeds were spread on blotting paper for 6 h and dried at room temperature (25 °C). After treatment with plant hormones, seeds were prepared for planting in trays with dimension of 7 × 15 cm. Growth medium was prepared by mixing 1:1 peat moss and sand.

Traits measurement

After emergence, the number of germinated seeds was recorded on daily basis. Then, germination percentage, mean germination rate, seedling height (cm), root length (mm), stem diameter (mm), leaf length (cm), leaf width (cm) leaf number and seedling root fresh and dry weight (after 40 days) were calculated. Following equations were used for calculating germination traits:

Germination % = (total number of seeds/number of germinated seeds per day) ×100

Mean of germination rate (MGR)= ∑((number of germinated seeds per day)n/n-1)

Seed vigor index = Germination% × Mean of seedling height/100

In this equation, n is the number of days.

The length of seedling and root was measured with a caliper. Fresh and dry weights of root and seedling were measured using digital scales after drying in oven at 70 °C for 48 h.

Statistical analysis

The statistical analysis was based on a randomized completely design (CRD); with three replications. Analysis of variance was carried out with SAS software. The mean comparison was performed with Duncan's test at ($p \leq 0.01$).

Results

Germination indices

Seed germination of different cultivars was significantly affected by priming treatments. The results showed that the effect of cultivar, GA_3, NAA and their interactions were significant ($p \leq 0.01$) for germination percentage, germination rate, and seed vigor index (Table 1). Pretreated seeds with different concentrations of plant hormones showed significantly higher germination percentage as compared to control. The highest germination percentage (85.98%) was recorded in 500 ppm GA3 and 100 ppm NAA in California Wonder 310 cultivar as compared to control (31.9%). In all cultivars, the highest germination percentage was obtained from 500 ppm GA_3 and 100 ppm NAA, and the lowest germination percentage was recorded in control (Table 2). The germination rate was significantly increased by seed priming. California Wonder 310 cultivar pretreated with 500 ppm GA_3 and 100 ppm NAA exhibited maximum germination rate (0.85) and minimum germination rate (0.31) was observed in unprimed California Wonder seeds (Table 2). Seed vigor index was significantly improved in *Capsicum annum* seeds primed with GA_3 and NAA as compared to the unprimed. In general, the maximum seed vigor index (749.6) was attained from treatment of 0 ppm GA_3 and 100 NAA in California Wonder 300 and California Wonder cultivars as compared to respective controls (159.1) (Table 2).

Growth characteristics

According to the obtained results, all studied traits were affected by the seed treatments with plant hormones and they showed significant difference with the control (non-primed seeds). Seedling height (cm), root length (cm), leaf number, stem diameter (mm), leaf length (cm), leaf width (cm), seedling dry and fresh weights (g) and root dry and fresh weights (g) were significantly affected by different concentrations of GA_3 and NAA (Table 3). It was observed that seed priming treatments increased seed germination and shoot height of all cultivars in the present study. The highest shoot height achieved at 500 ppm GA_3 and 100 ppm NAA in California Wonder 300 cultivar, but the lowest shoot height was obtained in 500 ppm GA_3 and 100 ppm NAA in California Wonder 310 cultivar (Table 4). Leaf number was higher in the seedlings germinated from primed seeds with GA_3 than in non-primed seeds. The maximum leaf number (3.96) was obtained from the interaction of 500 ppm GA_3 and 0 ppm NAA in California-Wonder 310 cultivar. The minimum leaf number (3.63) was observed from control in California Wonder 300 cultivar (Table 4). Leaf number was higher in the seedlings germinated from primed seeds with GA_3 than in non-primed seeds. The maximum leaf number (3.96) was obtained from the interaction of 500 ppm GA_3 and 0 ppm NAA in California-Wonder 310 cultivar. The minimum leaf number (3.63) was observed from control in California Wonder 300 cultivar (Table 4). In the present study, seed priming caused increase in shoot and root fresh weights. The highest shoot fresh weight (6.62 g) and root fresh weight (3.46g) were obtained from the 500 ppm GA_3 and 100 ppm NAA in the California-Wonder 300 cultivar, respectively (Table 4). The lowest shoot (3.23 g) and root (1.61 g) fresh weights were obtained from control of Cadia and California Wonder cultivars, respectively.

Table 1. Analysis of effects of different concentration of the GA_3 and NAA on germination characteristics of five cultivars of pepper

s.o.v	df	Mean squares		
		Germination (%)	Germination Rate	Seed Vigor Index
Cultivar	4	80.79**	0.008**	55752.21**
Gibberellin (GA_3)	2	13577.89**	1.35**	1500041.73**
Naphthaleneacetic acid (NAA)	2	1465.77**	0.146**	273252.46**
Cultivar× GA_3	8	60.15**	0.006**	6313.74**
Cultivar× NAA	8	5.33**	0.0005**	2971.92**
GA_3× NAA	4	180.04**	0.018**	40629.40**
Cultivar× GA_3× NAA	16	11.59**	0.001**	1706.79**
Experimental error	90	1.43**	0.0001**	239.15
C.V	-	2.29**	2.29**	4.03

*, ** = Significant at 5 % and 1%, respectively, NS= Non-significant

The effect of pepper cultivars and the interaction between pepper cultivars and plant hormones were not significant for dry weight traits of five pepper cultivars, but the single effect of GA_3 and NAA on this trait was significant ($p \leq 0.01$) (Table 3). The concentration of 500 ppm GA3 showed the highest shoot (0.58 g) and root (0.28 g) dry weights and the lowest shoot (0.44 g) and root (0.22 g) dry weights were observed in control. In NAA treatments, the highest shoot (0.53g) and root (0.23) dry weights were observed in 100 ppm NAA and the lowest shoot (0.42g) and root (0.16g) dry weights were observed in the control (Table 5). Seed priming significantly affected the stem diameter. The highest stem diameter (26.91 mm) was found in the concentration of 500 ppm GA_3 and 100 ppm NAA in Cadia cultivar and the lowest stem diameter (12.92 mm) obtained from control in the California Wonder 300 cultivar (Table 4). Leaf length but not leaf width was significantly affected by seed priming. Leaf length of plants from primed seeds was significantly improved compared to the control. The concentration of 500 ppm GA_3 and 100 ppm NAA exhibited the highest leaf length (5.36cm) in the Cadia cultivar but control treatment showed lowest stem diameter (75.7 cm) in California Wonder 300 cultivar (Table 4).

Table 2. Interaction effect of different concentration of the GA_3 and NAA on germination characteristics of five cultivars of pepper

Factor		Mean comparison								
		Germination (%)			Germination Rate			Seed Vigor Index		
		NAA			NAA			NAA		
		0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm
Marquiza	GA3(0 ppm)	33.98uv	40.3opq	38.58qrs	0.33uv	0.40pq	0.38qrs	17401uv	224.9r-t	209.31rst
	GA3(250 ppm)	42.38no	48.55k	50.96jk	0.42op	0.48 l	0.50jk	274.25o	318.53n	364.87lm
	GA3(500 ppm)	53.38hi	65.09e	76.92c	0.53hi	0.65e	0.76c	426.2 lm	477.16i	697.68c
Cadia	GA3(0 ppm)	32.83uv	37.84rs	39.75pqr	0.32uv	0.37rs	0.39qrs	159.1v	206.52st	238.7pqr
	GA3(250 ppm)	43.59mn	49.44jk	50.66jk	0.43no	0.49kl	0.50jkl	266.71op	326.03n	357.78m
	GA3(500 ppm)	61.50f	66.37e	79.90b	0.61f	0.66e	0.79b	426.27j	326.03hi	643.46de
California wonder	GA3(0 ppm)	31.97v	33.74uv	39.80pqr	0.31v	0.33uv	0.39rq	160.57v	311.2rst	270.17o
	GA3(250 ppm)	43.19mn	48.63k	52.14ij	0.43no	0.48kl	0.52ij	275.32o	489.07kl	418.42jk
	GA3(500 ppm)	66.23e	71.96d	81.24b	0.66e	0.71d	0.81b	424.70j	596.37f	737.21b
California wonder 310	GA3(0 ppm)	32.97uv	34.62u	39.07qrs	0.32uv	0.34u	0.39qrs	204.98st	225.4rst	259.3opq
	GA3(250 ppm)	45.34lm	49.05k	54.83gh	0.45mn	0.49kl	0.54gh	312.80n	354.84m	435.58j
	GA3(500 ppm)	64.21e	76.37c	85.98a	0.64e	0.76c	0.85a	508.9gh	623.92e	749.64b
California wonder 300	GA3(0 ppm)	35.07tu	37.07st	42.07nop	0.35tu	0.37st	0.42op	200.90tu	235.5qrs	306.79n
	GA3(250 ppm)	46.13 l	50.92jk	55.75g	0.46m	0.50ik	0.55g	324.62n	402.97jk	501.43hi
	GA3(500 ppm)	65e	73.50d	81.15b	0.65e	0.73d	0.81b	531.39g	664.13d	819.22a

In a column, means with the same letters are not significantly different

Table 3. Analysis of effects of different concentration of the GA3 and NAA on growth characteristics of five cultivars of pepper

s.o.v	df	Mean squares										
		Plant height (cm)	Root length (cm)	Leaf number	Leaf area (cm^2)	Shoot fresh weight (gr)	Shoot dry weight (gr)	Root fresh weight (gr)	Root dry weight (gr)	Stem diameter(mm)	Leaf length (cm)	Leaf width (cm)
Cultivar	4	815.56**	1.97**	0.024^{ns}	10044.72^{ns}	4.52**	0.054^{ns}	1.13**	0.01^{ns}	2.87**	2.78**	0.33^{ns}
(GA3)	2	1738.14**	116.31**	0.29**	8989.94^{ns}	23.67**	0.170**	5.91**	0.04**	15.58**	15.85**	0.05^{ns}
(NAA)	2	1513.16**	25.70**	0.69**	9347.86^{ns}	8.13**	0.128**	2.03**	0.03**	5.62**	5.36**	0.05^{ns}
Cultivar× GA3	8	1885.01**	1.31**	0.068**	10028.97^{ns}	0.181**	0.028^{ns}	0.04**	0.007^{ns}	0.12**	0.21**	0.67^{ns}
Cultivar× NAA	8	83.36**	0.49**	0.037*	9983.25^{ns}	0.477**	0.008^{ns}	0.051**	0.002^{ns}	0.27**	0.72**	0.67^{ns}
GA3× NAA	4	53.09**	1.067**	0.099**	10027.01^{ns}	0.206**	0.003^{ns}	0.119**	0.002^{ns}	0.18**	0.81**	0.11^{ns}
Cultivar× GA3× NAA	16	66.35**	0.95**	0.036**	9954.85^{ns}	0.100**	0.005^{ns}	0.025**	0.001^{ns}	0.053**	0.035**	1.35^{ns}
Experimental error	90	6.27	0.064	0.014	9970.266	0.020	0.025	0.005	0.006	0.019	0.01	1.86
C.V	-	3.98	2.35	3	19.35	3.04	21.33	3.04	21.33	2.51	2.51	6.82

*, ** = Significant at 5 % and 1%, respectively, NS= Non-significant

Table 4. Interaction effect of different concentration of the GA_3 and NAA on growth characteristics of five cultivars of pepper

Factor		Plant height (cm)			Root length (cm)			Leaf number			Stem diameter (mm)			Shoot fresh weight (gr)			Leaf length (cm)			Root fresh weight (gr)		
		NAA			NAA			NAA			NAA			NAA			NAA			NAA		
		0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm	0 ppm	50 ppm	100 ppm
Marquiza	GA_3 (0 ppm)	45mno	48.33qrs	59.76rst	8.67stu	9.35opq	9.04o-r	3.66ij	4b-h	3.96c-h	13.57pq	14.84o	14.32op	3.23op	3.71n	3.58no	8.14pq	8.9o	8.59op	1.69pq	1.85o	1.79op
	GA_3 (250 ppm)	44.23st	56.3nop	57.76no	10.44j-m	10.86hij	11.76de	4.20abc	3.96c-h	3.93c-h	17.25jkl	17.49i-l	19.09 def	4.31ijk	4.37hij	4.77def	10.35jkl	10.49h-j	11.45def	2.15jkl	2.18h-k	2.38def
	GA_3 (500 ppm)	58.43no	65.64i-l	74.10ef	11.22e-h	12.56c	15.85a	3.96c-h	4.20abc	4.06a-f	18.49d-h	19.54d	24.18b	4.62d-h	4.88de	6.04b	11.09d-h	11.72d	14.51b	2.31d-h	2.24d	3.02b
Cadia	GA_3 (0 ppm)	66.97h-k	70.62f-i	72.30fg	8.24u	8.84q-t	9.68no	3.77a-d	4.15a-d	4.11hij	12.92q	14.62o	16.02mn	3.23p	3.65n	4lm	7.75q	8.77o	9.61mn	1.61q	1.82o	2mn
	GA_3 (250 ppm)	64klm	67.45g-k	82.76bc	9.98mn	10.67ijk	11.38e-h	3.85c-h	3.85f-j	3.97f-j	16.31lm	17.57i-h	18.79d-g	4.07klm	4.39hij	4.69d-g	9.78lm	10.54h-j	11.27d-g	2.03lm	2.19h-k	2.34d-g
	GA_3 (500 ppm)	46.35rs	59.7mno	60.80lmn	11.62def	11.75de	12.54c	3.8a-d	4.12a-d	4.15f-j	18.5d-g	19.59d	21.46c	4.62d-h	4.89d	5.36c	11.1d-h	11.75d	12.87c	2.31d-h	2.44d	2.68c
California wonder	GA_3 (0 ppm)	47.70rs	45.05rst	49.95qr	8.45tu	9.32o-r	9.68no	3.65d-i	3.85f-j	3.90ij	13.4pq	16.7klm	18.1g-j	4.25op	4.17jkl	4.52f-i	8.04pq	10.02klm	10.86e-i	1.67pq	2.08klm	2.26f-j
	GA_3 (250 ppm)	68.25g-k	69.20f-k	77.85de	10.56j-l	11.30e-h	11.72def	3.95c-h	4.15a-d	3.95c-h	17k-m	21.4c	21.4c	4.27i-l	5.35c	5.35c	10.2j-m	12.84c	12.84c	2.12j-m	2.76c	2.67c
	GA_3 (500 ppm)	64.2klm	71.20fgh	66.15h-k	11.03ghi	11.57def	12.60c	3.85ab	4.20abc	4.25f-j	17.1k-m	22.1c	24.2b	4.27i-l	5.52c	6.05b	10.26j-m	13.26c	14.52b	2.13j-m	2.76c	3.02b
California wonder 310	GA_3 (0 ppm)	52.70pq	56.6nop	55.96nop	8.81rst	9.40op	9.74no	3.76a-f	4.13a-d	4.10hij	16.57klm	17.36i-l	17.7g-k	4.14jkl	4.34h-k	4.42g-j	9.94klm	10.41i-l	10.62h-k	2.07klm	2.17il	2.21g-k
	GA_3 (250 ppm)	44.83st	46.43rs	38.84u	10.07l-n	10.45j-m	11.31e-h	3.9a	3.9d-i	4.26d-i	18.39e-i	19.28de	21.18c	4.59e-h	4.82de	5.29c	11.03e-i	11.57de	12.7c	2.29e-i	2.41de	2.64c
	GA_3 (500 ppm)	69.36f-i	80.94dc	87.11b	11.56d-g	11.55d-g	12.66c	3.96a	4.06a-f	4.26c-h	21.13c	21.78c	23.24b	5.28c	5.44c	5.81b	12.67c	13.07c	13.94b	2.64c	2.72c	2.90b
California wonder 300	GA_3 (0 ppm)	64.76jkl	67.53g-k	84.40bc	8.42tu	8.42tu	10.05lmn	3.63j	3.9d-i	4.14a-d	15.27no	16.94klm	19.44de	3.81mn	4.23i-l	4.86de	9.16no	10.16klm	11.66de	1.90no	2.11klm	2.43de
	GA_3 (250 ppm)	41.40tu	55.53op	57.43nop	10.3k-m	10.3k-m	12.07d	3.86f-j	4.03a-g	4.13a-d	18.76d-g	21.35c	23.99b	4.69d-g	5.23c	5.99b	11.26d-g	12.81c	14.39b	2.34d-g	2.66c	2.99b
	GA_3 (500 ppm)	76.92de	84.09bc	95.59a	11.65d-f	11.65d-f	13.60b	4.13a-d	4.16abc	4.23ab	21.79c	24.09b	26.91a	5.44c	6.02b	6.72a	13.07c	14.45b	16.14a	2.72c	3.01b	3.46a

Mean comparison.
In a column, means with the same letters are not significantly different

Table 5. Effect of different concentration of the GA_3 and NAA on shoot and root dry weight

Traits	Mean comparison					
	GA_3			NAA		
	0 ppm	250 ppm	500 ppm	0 ppm	50 ppm	100 ppm
Shoot dry weight (gr)	0.44c	0.5b	0.56a	0.45c	0.52b	0.58a
Root dry weight (gr)	0.22c	0.25b	0.28a	0.21c	0.26b	0.29a

In a row, means with the same letters are not significantly different

Discussion

Germination percentage

According to Rouhi et al. (2012), increase in the rate of germination and germination percentage are likely dependent on gibberellin activity. In fact, gibberellins stimulate hydrolysis enzymes, especially alpha-amylase, which results in seed germination (Yamaguchi, 2008). Different reports indicated that seed priming increases the percentage and uniformity of seeds germination (Kaya et al., 2006; Ghassemi-Golezani et al., 2008). Yogananda et al. (2004) reported that treatment of pepper seeds with 200 ppm gibberellic acid is the best concentration for percentage of germination (91.75%) when compared with its lower concentrations. Similar results were also obtained in the present study. Furthermore, a combination of gibberellic acid + cytokinin and 40 ppm naphthalene acetic acid had a significant improving effect on pepper germination (81.5%) in comparison with the control treatment.

Germination rate

Priming with plant hormone caused a positive effect on germination rate of pepper seeds. Eisvand et al. (2015) showed that in carrot seeds, germination rate increases in response to priming with gibberellic acid and salicylic acid (100 ppm). Tabatabaei (2014) reported that seed priming with gibberellic acid and salicylic acid increased the seed germination rate of wheat plants.

Seed vigor index

The seeds vigor index can be improved by seed priming, which increases the rate and uniformity of germination (Demir and Van De Venter, 1999). Our results are similar to those studies that showed that seed priming enhances seed vigor index in plants. It has been shown that gibberellic acid (100 ppm) can increase the vigor index of chickpea seeds (Eisvand et al., 2015). Furthermore, it has been shown that lamb's seed priming (hydropriming and salicylic acid priming) increases the rate and percentage of germination and seed vigor index (Mohammadi and Shekari, 2015).

Shoot height

It seems that the increase in stem length is due to an increase in the length of the internodes. Mohammadi and Shakari (2015) reported that priming of lentil seed (hydropriming and salicylic acid) increases the length of stems and roots. Basra et al. (2006) reported that rice seed priming with salicylic acid and gibberellic acid enhances germination rate and seedling growth.

Root length

Some concentrations of gibberellic acid increased seedling length, root length, the fresh and dry weights of maize (*Zea mays* L.) root under salinity stress conditions (Ghodrat et al., 2010). Priming with Indole butyric acid and naphthaleneacetic acid has been reported to promote the length of root and shoot in a concentration of 50 ppm in Asparagus (Yuan-Yuan et al., 2010). The significant increase in the shoot and root length in primed seeds may be due to its involvement in cell elongation or cell division and the meristematic growth (Khan et al., 1992). Moreover, seed treatments with plant hormones such as IAA, IBA and NAA enhance root formation and development (De Castro *et al.*, 2000).

Leaf number and leaf area

In accordance with finding of present study, treatment with 200 ppm gibberellic acid in comparison with control increased plant height, the number of leaves and number of primary and secondary branches of eggplant (Gavaskar and Anburani, 2004). In our study, the effect of seed priming on leaf area was not significant, which is not in agreement with other studies. Chaudhary et al. (2006) reported that plant growth regulators had a significant effect on growth of pepper cultivars (Jwala and Suryamukhi) and the concentration of 40 ppm NAA produced the highest leaf area index in pepper cultivars. Rana and Singh (2012) studied the effect of plant growth regulators on growth, yield, and quality of pepper fruit; they showed that priming with 50 ppm NAA significantly increases plant height, number of branches and leaf area.

Fresh and dry weight

Priming has a positive effect on the fresh and dry weights of shoot and root in pepper seedlings, which is in agreement with the previous reports. Hydropriming and hormonal priming with gibberellic acid and salicylic acid increased the dry and fresh weights of carrot root (Eisvand et al., 2015). Hydropriming (for 24 h) and osmopriming (with 4% mannitol) in chickpea seeds caused elongated roots and stems and increased dry weight as compared to un-primed seeds (Kaur et al., 2005). One of the reasons for the increase of dry weight by gibberellic acid hormones is probably due to increase in growth and cell division by influencing the synthesis and activity of the auxin and cytokinin. Siddik et al. (2015) showed that NAA significantly improves morphological characteristics such as plant height, leaf number per plant, number of branches per plant, fresh and dry weights of root and shoot in sesame. The results of Vijayakumari (2002) indicated that shoot and root weights were improved by seed priming with 200 ppm gibberellic acid.

Stem diameter

The results of present study showed that stem diameter in all cultivars increased by higher gibberellic acid concentrations, so that the maximum stem diameter was observed in 500 ppm gibberellic acid. These results are in accordance with the study of Saravaiya et al. (2010), who reported that seed treatment with 5 mg/L gibberellic acid increases plant height, plant volume, stem length, stem diameter and dry weight of cabbage.

Leaf length and width

In the present study the highest leaf length was obtained from the interaction of high levels of gibberellic acid and NAA. These results are in consistent with the study of Vijayakumari (2002) on *Andrographis paniculata* plant but the width of the leaf was not affected by priming with gibberellic acid and NAA.

Conclusion

In conclusion, different concentrations of plant hormones caused a significant improving effect on germination and growth of pepper seedlings. In the present investigation, the highest germination percentage and germination rate were observed in parsley cultivar due to hormonal priming treatments as compared with control in other studied cultivars. The growth of treated pepper cultivars was better than unprimed seedlings. Therefore, the use of gibberellic acid and NAA alone or in combination can be an effective approach to improve germination and growth of pepper plants. The involved mechanism at physiological and biochemical levels for this improvement in pepper seedlings needs to be studied in future.

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